

# Overview of the U.S. Aviation Climate Action Plan, SAF Grand Challenge, and Efforts on Aviation Induced Cloudiness at FAA

NASA Operationalizing Contrail Avoidance Virtual Workshop

Dr. Prem Lobo  
Office of Environment and Energy  
Federal Aviation Administration

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## United States 2021 Aviation Climate Action Plan



# White House Sustainable Aviation Event

On September 9, 2021, government and industry leaders met to discuss actions and make new announcements regarding efforts to address aviation and climate change in the near-term, with a view to long-term ambition.

Key federal actions include:

- A new Sustainable Aviation Fuel Grand Challenge to inspire the dramatic increase in the production of sustainable aviation fuels to at least 3 billion gallons per year by 2030;
- An increase in R&D activities to demonstrate new technologies that can achieve at least a 30% improvement in aircraft fuel efficiency;
- Efforts to improve air traffic and airport efficiency to reduce fuel use, eliminate lead exposure, and ensure cleaner air in and around airports; and
- The demonstration of U.S. leadership both internationally and through the federal example.

“...the Administration also plans to release an aviation climate action plan in the coming months, which will set forth a comprehensive plan for aviation.”



# Aviation Climate Action Plan

- International Civil Aviation Organization (ICAO) – “State Action Plans”
- Plan builds on ongoing FAA Environment & Energy Program – long-term focus on reducing climate impacts of aviation
- Administration focus on climate – Achieving net zero emissions economy-wide by 2050
- Climate Action Plan Press Release:  
<https://www.faa.gov/newsroom/us-releases-first-ever-comprehensive-aviation-climate-action-plan-achieve-net-zero>
- Climate Action Plan Document:  
[https://www.faa.gov/sites/faa.gov/files/2021-11/Aviation\\_Climate\\_Action\\_Plan.pdf](https://www.faa.gov/sites/faa.gov/files/2021-11/Aviation_Climate_Action_Plan.pdf)



# U.S. Aviation Climate Goal

To be effective, a goal should be clear, achievable, and ambitious with specific actions that can be taken to achieve it. The goal outlined below contributes to the broader objective to achieve net-zero GHG emissions economy-wide by 2050.

## ***U.S. Aviation Climate Goal: Net-Zero GHG Emissions\* from U.S. Aviation Sector\*\* by 2050***

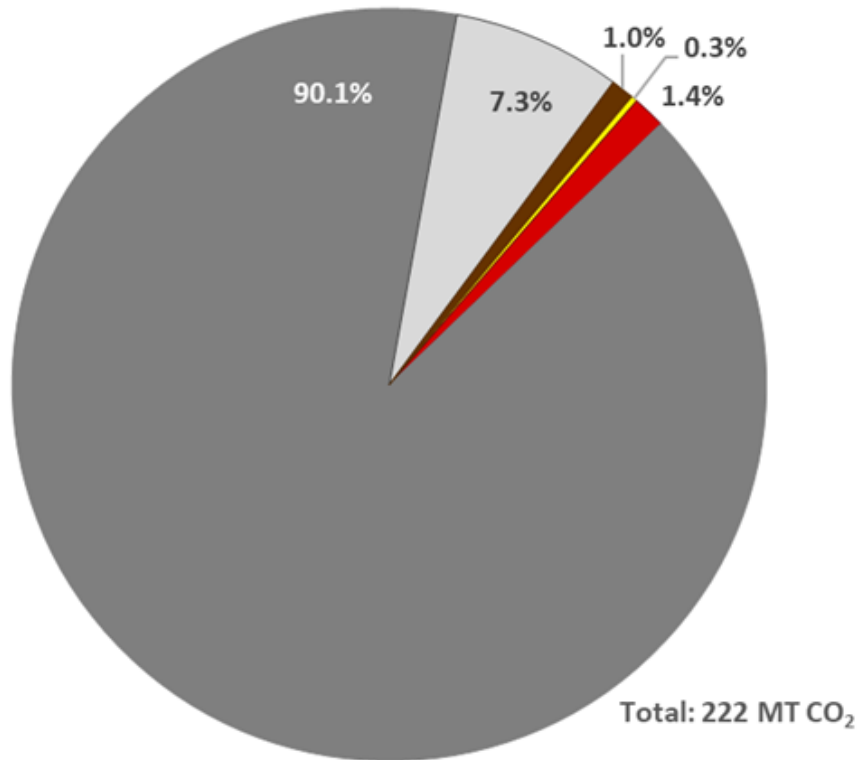
\* Aviation GHG emissions include life cycle carbon dioxide (CO<sub>2</sub>), nitrous oxide (N<sub>2</sub>O), and methane (CH<sub>4</sub>) emissions. Aircraft engines produce negligible amounts of nitrous oxides and methane, so this plan has a focus on aviation combustion CO<sub>2</sub> emissions and well-to-tank life cycle GHG emissions (CO<sub>2</sub>, N<sub>2</sub>O, and CH<sub>4</sub>). The U.S. Aviation 2050 Goal is based on emissions that are measurable and currently monitored. Research is ongoing into the climate impacts of aviation-induced cloudiness and the indirect climate impacts of aviation combustion emissions (see section 7 for details on the climate impacts of aviation non-CO<sub>2</sub> combustion emissions).

\*\* This U.S. aviation goal encompasses CO<sub>2</sub> emissions from (1) domestic aviation (i.e., flights departing and arriving within the United States and its territories) from U.S. and foreign operators, (2) international aviation (i.e., flights between two different ICAO Member States) from U.S. operators, and (3) airports located in the United States.



# Analysis of U.S. Aviation CO<sub>2</sub> Emissions in 2019

U.S. Domestic & International\*  
Aviation CO<sub>2</sub> Emissions

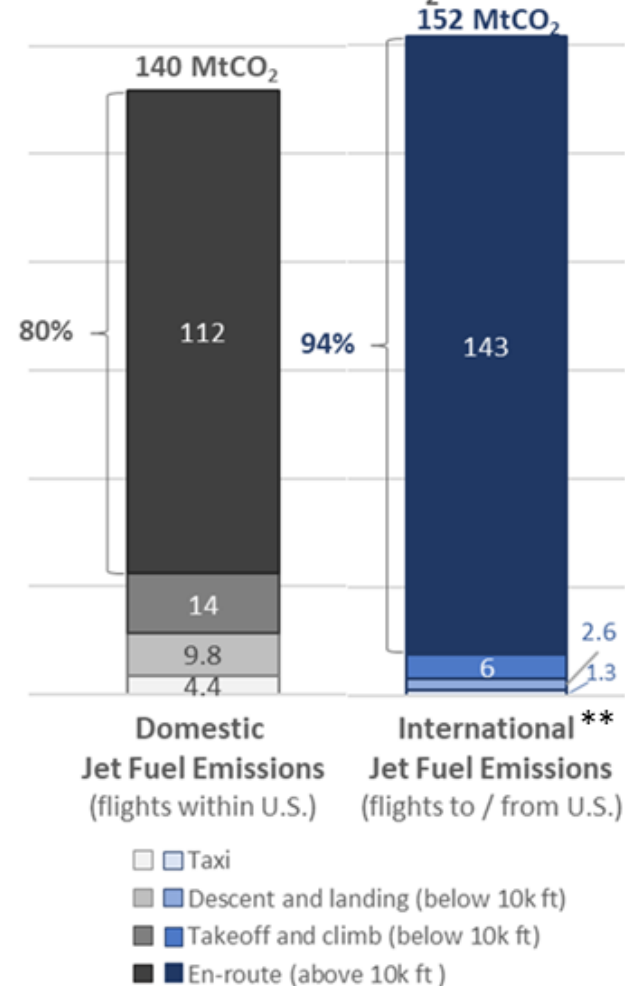


- Airport Scope 1 Emissions (from airport-owned or controlled sources) - 0.6 MT CO<sub>2</sub>
- Airport Scope 2 Emissions (due to use of purchased energy) - 3.1 MT CO<sub>2</sub>
- Domestic and International Jet Fuel Emissions (commercial flights) - 200 MT CO<sub>2</sub>
- Domestic and International Jet Fuel Emissions (GA flights) - 16 MT CO<sub>2</sub>
- Domestic and International Aviation Gasoline Emissions - 2 MT CO<sub>2</sub>

\* CO<sub>2</sub> emissions from (1) domestic aviation (i.e., flights departing and arriving within the United States and its territories) from U.S. and foreign operators and (2) international aviation (i.e., flights between two different ICAO Member States) from U.S. operators (only). Airport scopes 1 and 2 added for this specific analysis (figure).

\*\* International aviation to / from the United States, regardless of the operator of the flights i.e., including both U.S. and foreign operators.

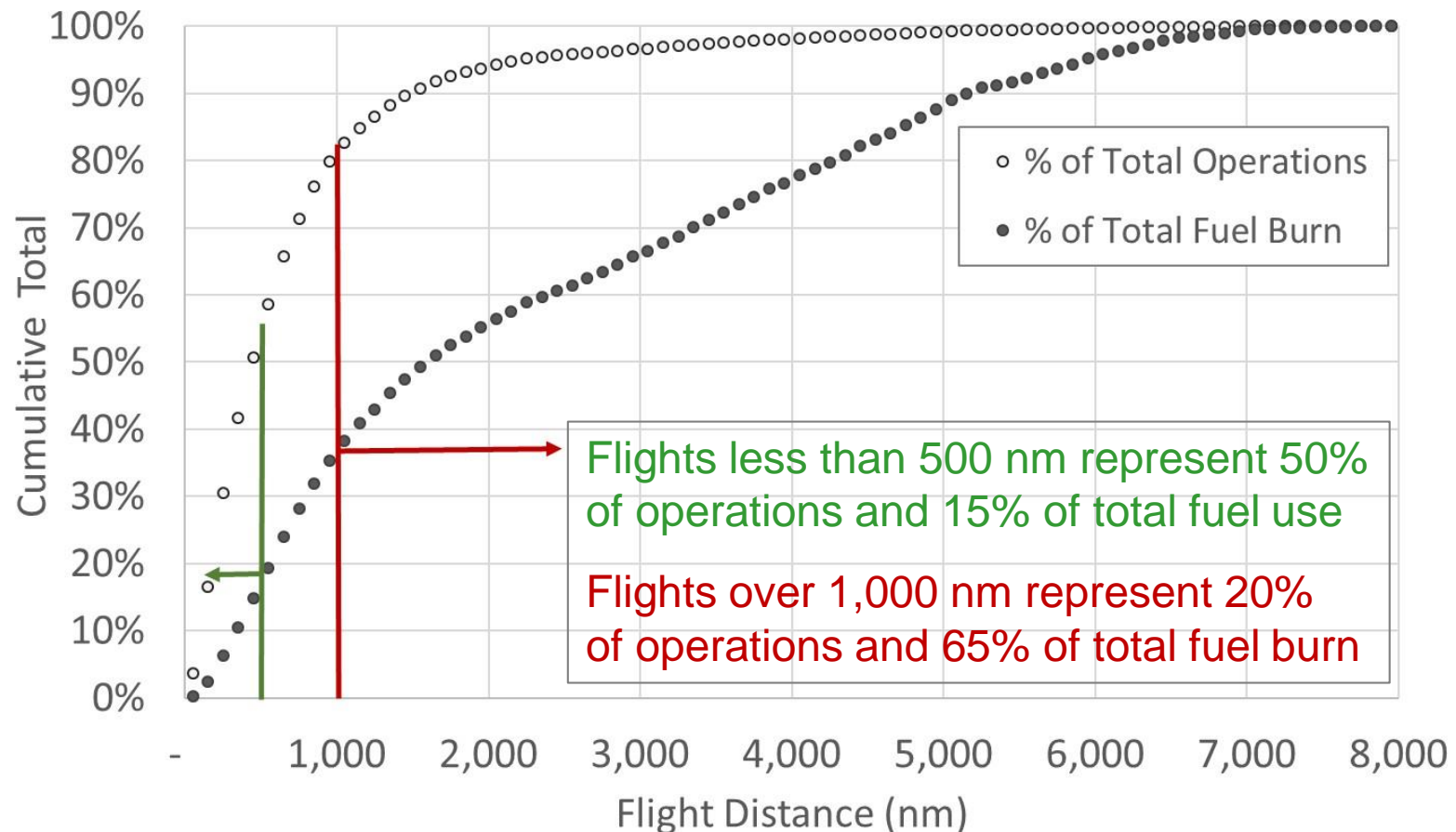
Detailed Analysis of Commercial  
Aviation Jet Fuel CO<sub>2</sub> Emissions



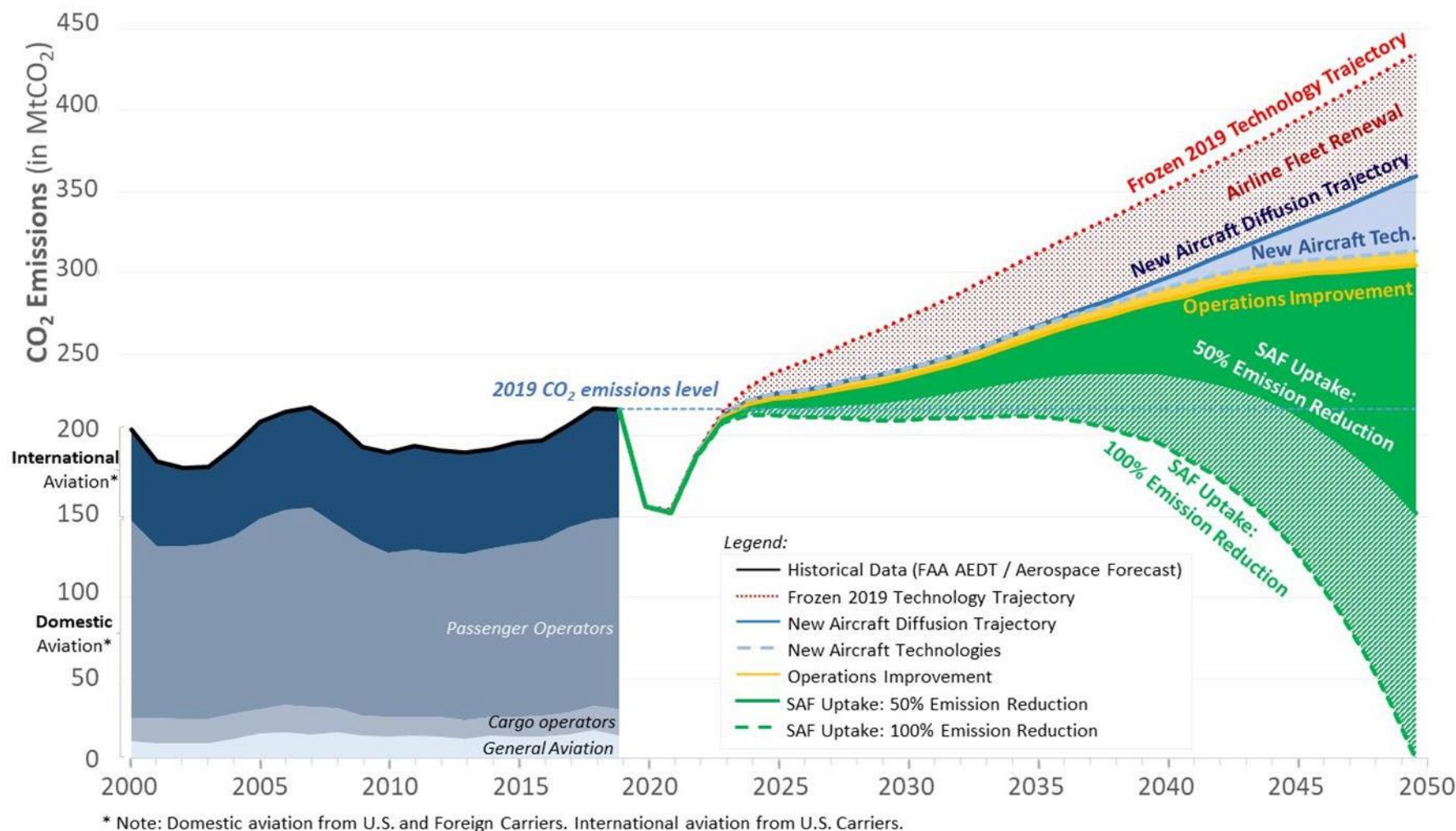


# Global Jet Fuel Use

- Global jet fuel use is driven by long-haul aviation
- SAF only option through 2050 for long distances



# Analysis of Future Domestic and International Aviation CO<sub>2</sub> Emissions



NOTE: Analysis conducted by BlueSky leveraging FAA Aerospace Forecast and R&D efforts from the FAA Office of Environment & Energy (AEE) regarding CO<sub>2</sub> emissions contributions from aircraft technology, operational improvements, and SAF



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# Full Report Contents

[https://www.faa.gov/sites/faa.gov/files/2021-11/Aviation\\_Climate\\_Action\\_Plan.pdf](https://www.faa.gov/sites/faa.gov/files/2021-11/Aviation_Climate_Action_Plan.pdf)

- Introduction
- Climate Goals and Approach
- Aircraft and Engine Technology Development
- Operational Improvements
- Sustainable Aviation Fuels
- International Leadership and Initiatives
- Airport Initiatives
- FAA Leadership on Climate, Sustainability and Resilience
- Non-CO<sub>2</sub> Impacts of Aviation on Climate
- Policy and Measures to Close the Gap





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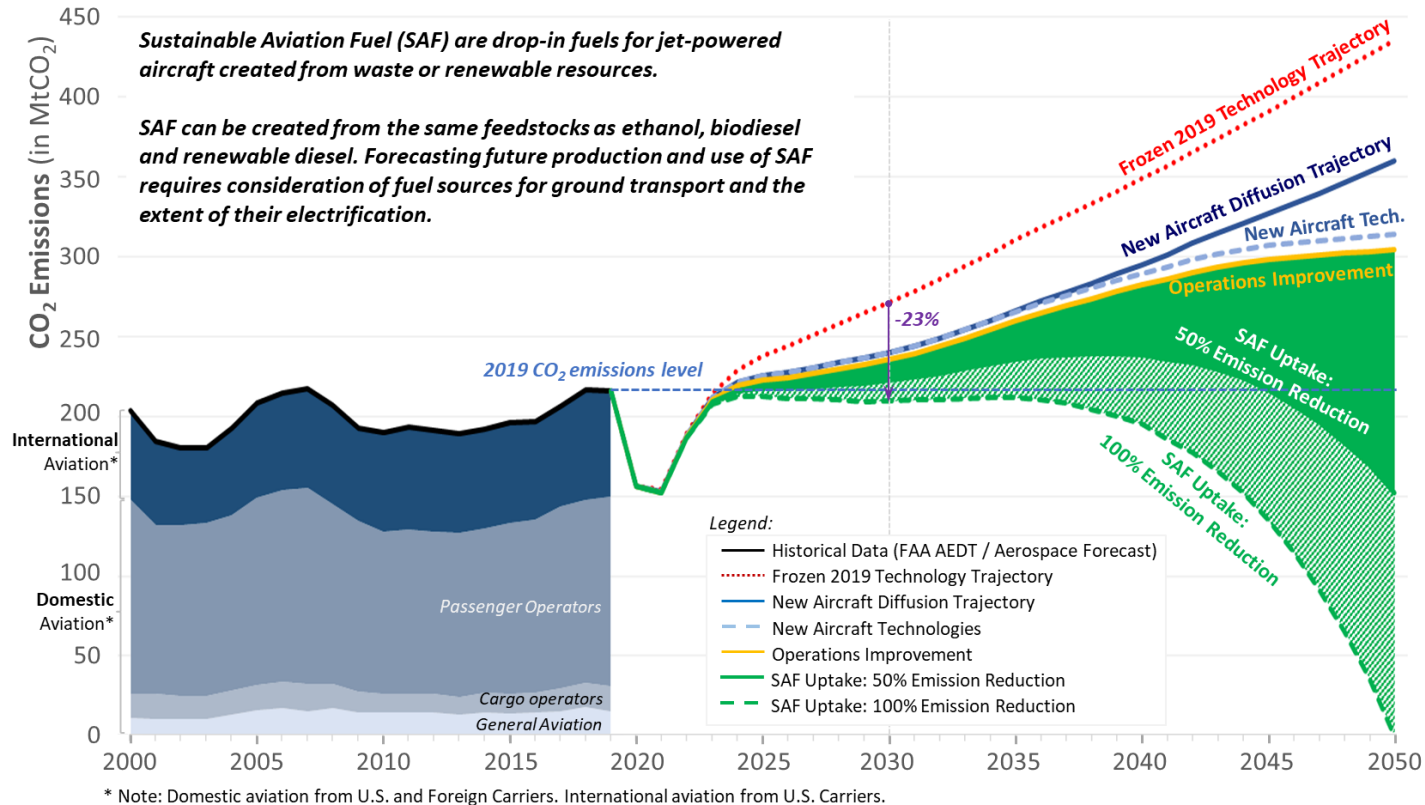
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# Sustainable Aviation Fuels

*Sustainable Aviation Fuels (SAF) will be critical to the long-term decarbonization of aviation. Through a range of policy instruments, including the SAF Grand Challenge, the USG will work with industry to rapidly scale up SAF production with the goal of meeting the fuel needs of U.S. aviation by 2050.*



# Jet Fuel

- Jet fuel is a critical component of the safe, reliable, and efficient global air transportation system
- Jet fuel provides a unique combination of properties that enable aircraft to safely carry hundreds of passengers and tons of freight for thousands of miles at high speed
  - Remains a liquid at very low temperatures of flight
  - Does not vaporize at low atmospheric pressures experienced in the upper atmosphere during cruise flight
  - Tolerates relatively high engine temperatures without breaking down and clogging fuel lines
  - Provides considerable energy both in terms of energy per unit mass and per unit volume
- While these properties play a key role in enabling today's aviation system, they also make it a difficult sector to decarbonize because they are hard to replace



# Sustainable Aviation Fuels (SAF)

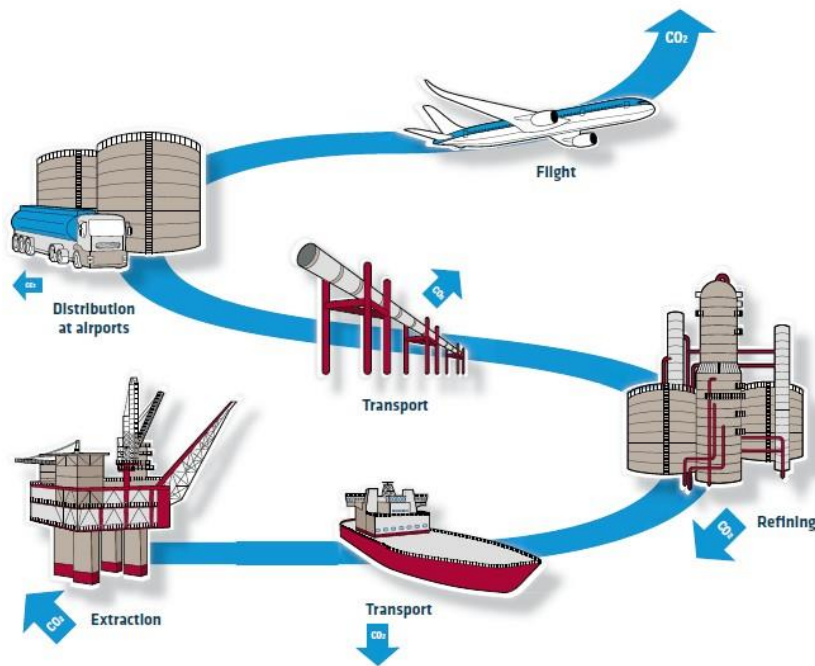
- SAF are “drop-in” liquid hydrocarbon fuels with the same performance and safety as conventional jet fuels produced from petroleum
- SAF are fully fungible with the existing fuel supply and can be used in the same infrastructure, engines, and aircraft
- SAF can be produced from renewable feedstocks, waste materials, and industrial waste gases
- Some types of SAF reduce emissions that impact air quality and contribute to the formation of contrails, which also impacts climate change



# Sustainable Aviation Fuels – Life Cycle Benefit

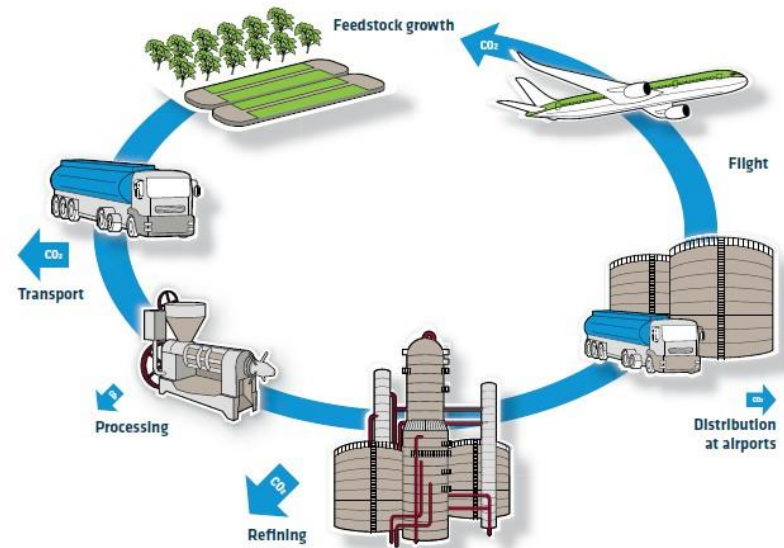
The extent to which any particular SAF provides a climate benefit depends on the SAF's life cycle emissions profile, taking into account the production, transportation, and combustion of the SAF, as well as indirect effects associated with these.

Carbon lifecycle diagram: fossil fuels



At each stage in the distribution chain, carbon dioxide is emitted through energy use by extraction, transport, etc.

Carbon lifecycle diagram: Sustainable aviation fuel



Carbon dioxide will be reabsorbed as the next generation of feedstock is grown.

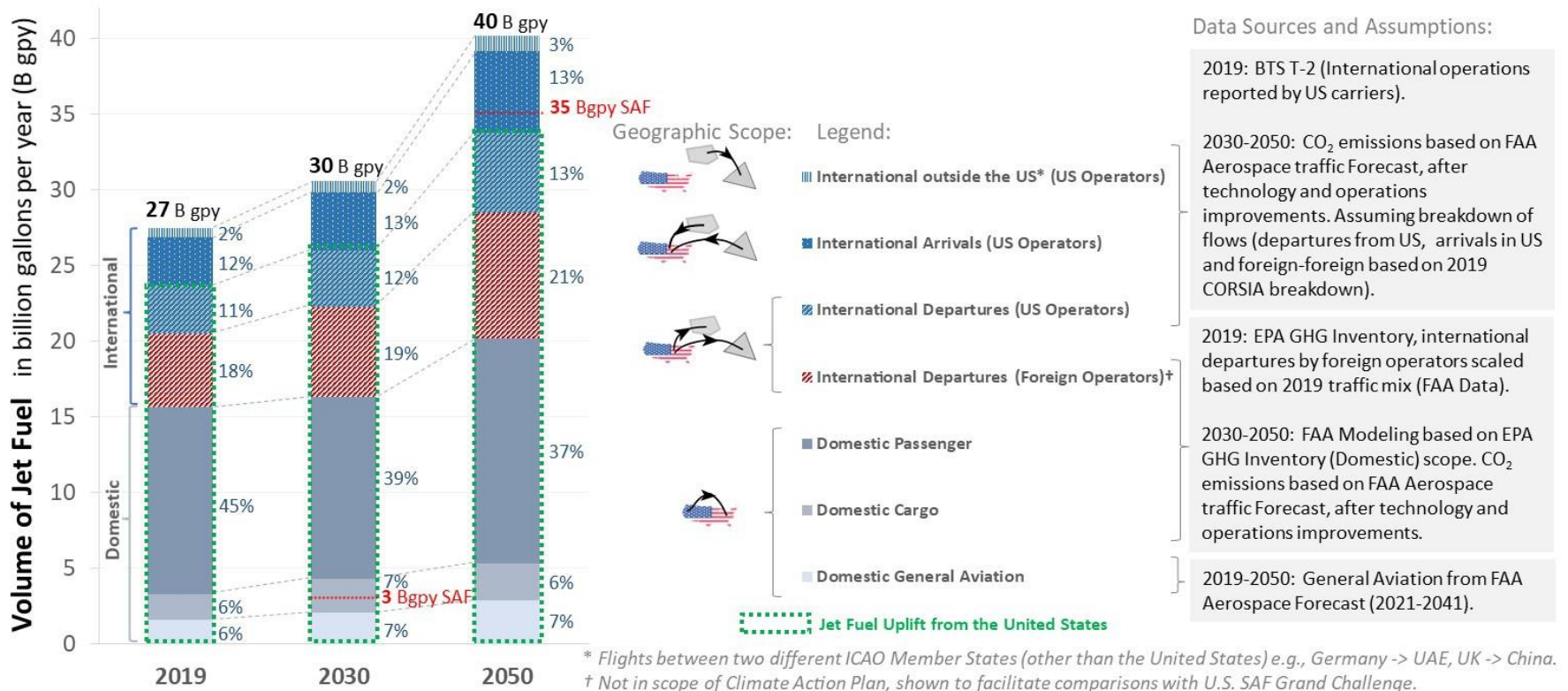
**Note:** the diagram above does not demonstrate the lifecycle process of SAF derived from municipal waste.



# SAF Grand Challenge

<https://www.energy.gov/eere/bioenergy/sustainable-aviation-fuel-grand-challenge>

*The US Government has identified the development and deployment of SAF as a key aviation climate priority. The USG has established a multi-agency effort led by the DOT, DOE, and USDA to implement the “SAF Grand Challenge” to reduce cost, enhance sustainability, and expand production and use of SAF that achieves a minimum of a 50% reduction in life cycle GHGs compared to conventional fuel.*



Potential demand for jet fuel in gallons per year (gpy) across domestic operations (by U.S. and Foreign Carriers).

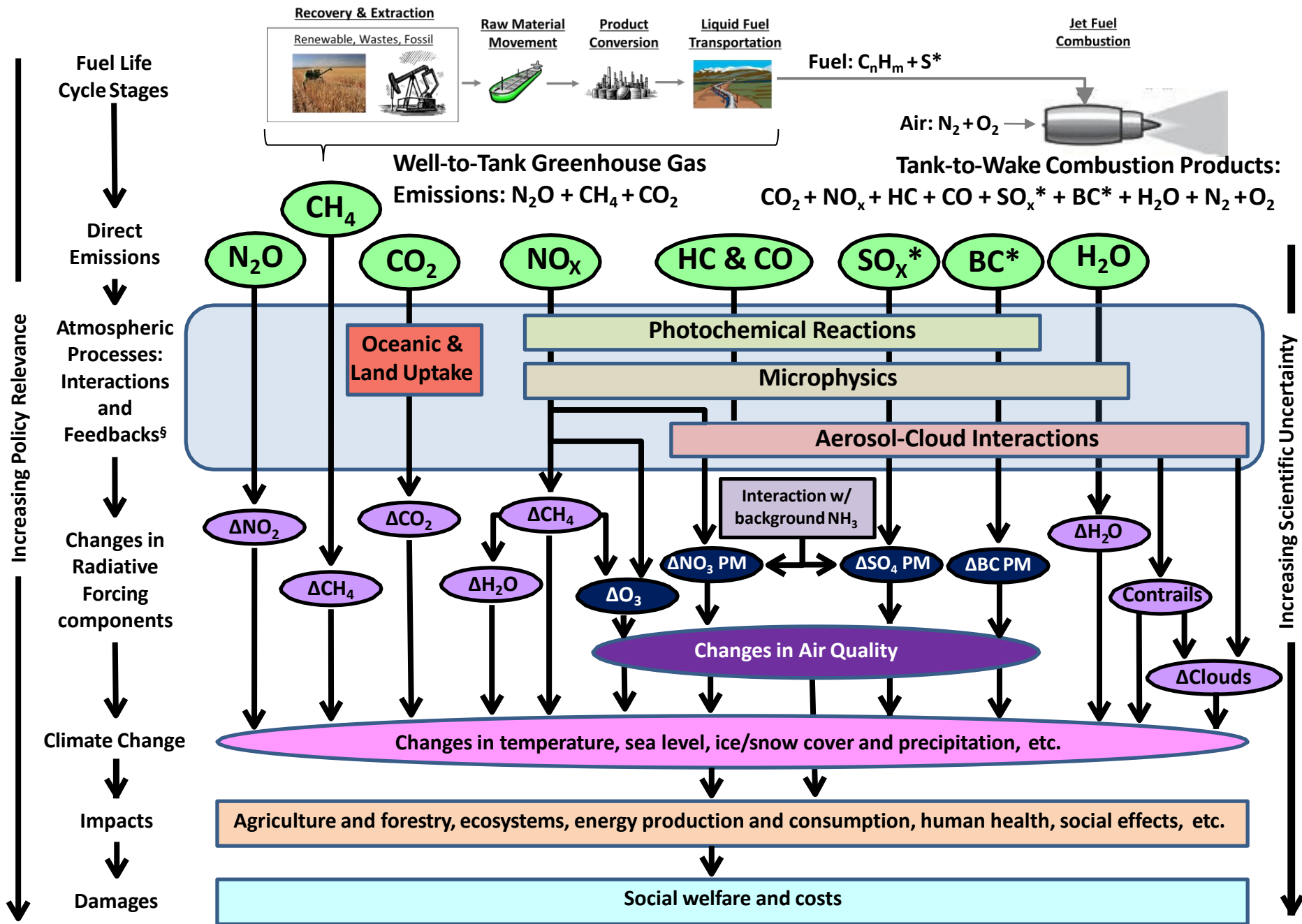
**Developing SAF Grand Challenge Roadmap – details provided at CAAFI Biennial General Meeting ([https://caafi.org/resources/CAAFI\\_CBGm\\_2022.html](https://caafi.org/resources/CAAFI_CBGm_2022.html))**

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<sup>§</sup>Account for radiative, chemical, microphysical and dynamical couplings along with dependence on changing climatic conditions and background atmosphere

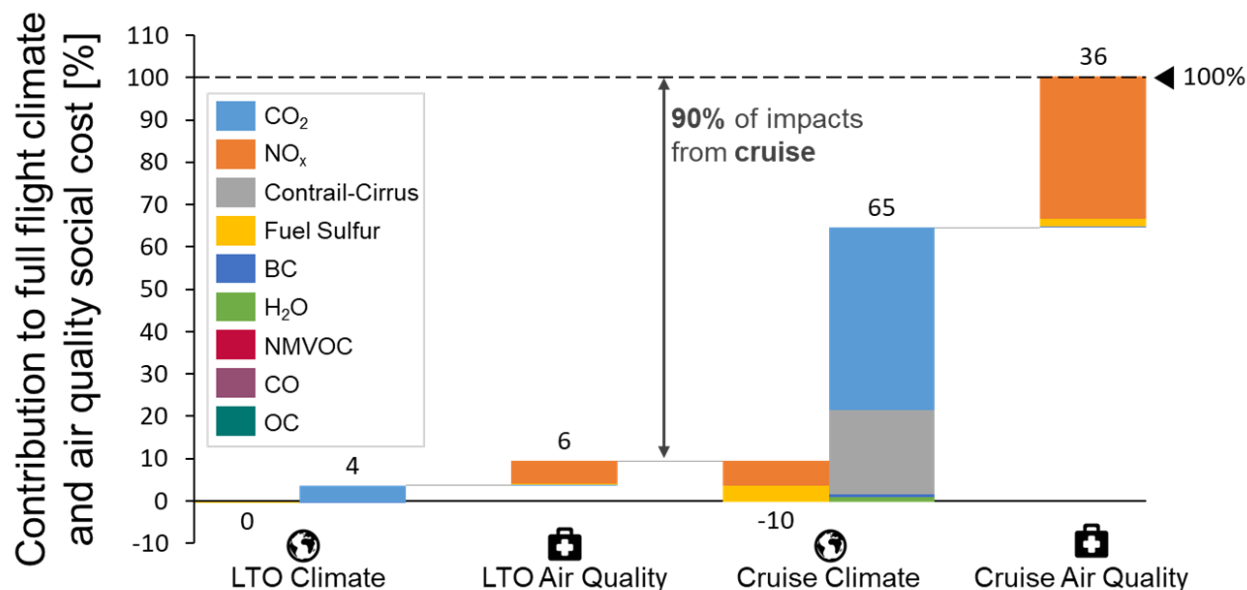
\*Sustainable aviation fuels can be produced with zero sulfur related emissions and reduced black carbon emissions

Modified from Brassuer et al 2016

# Impacts of Aviation Emissions

## Impacts of Full Flight Emissions on Air Quality, Climate, and Ozone

- Project continues long-standing FAA-funded effort at MIT to use analytical tools to model global movement and transformation of aircraft emissions as well as their impacts on surface air quality, global climate change, and the ozone layer
- Team have found that globally, impacts of cruise emissions on surface air quality are larger than those attributed to landing and takeoff (~16,000 premature mortalities<sup>1</sup> or 0.2% of the 9 million premature mortalities from combustion emissions globally<sup>2</sup>)
- However, the results have considerable uncertainty and we continue to do work to better understand the impacts of cruise emissions on surface air quality

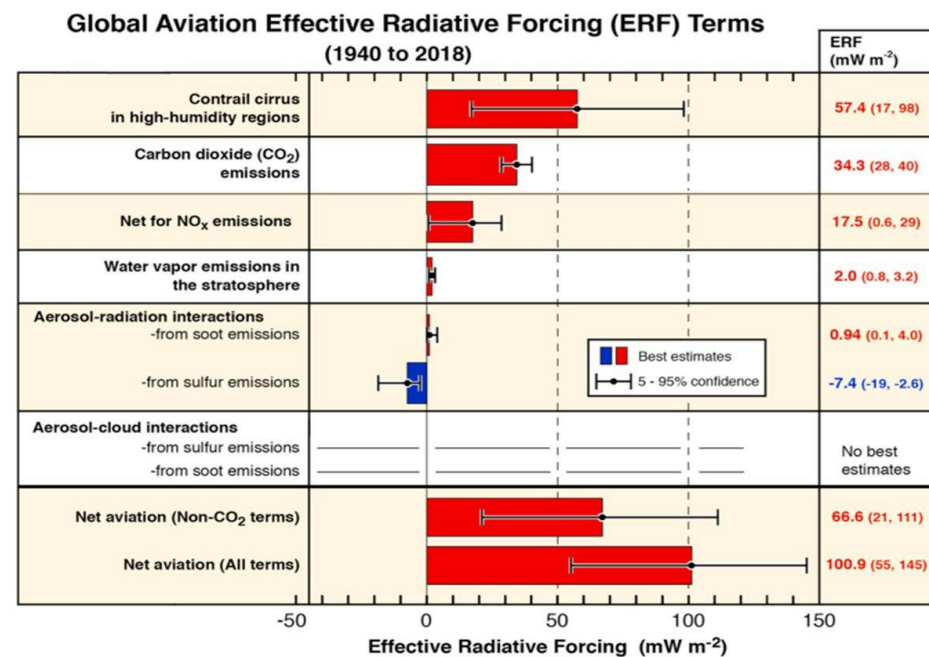


1. Grobler et al, *Environmental Research Letters* 2019. Data updated with more recent social cost of carbon, 3% discount rate; Country specific VSL.
2. Landrigan et al., *The Lancet* 2017



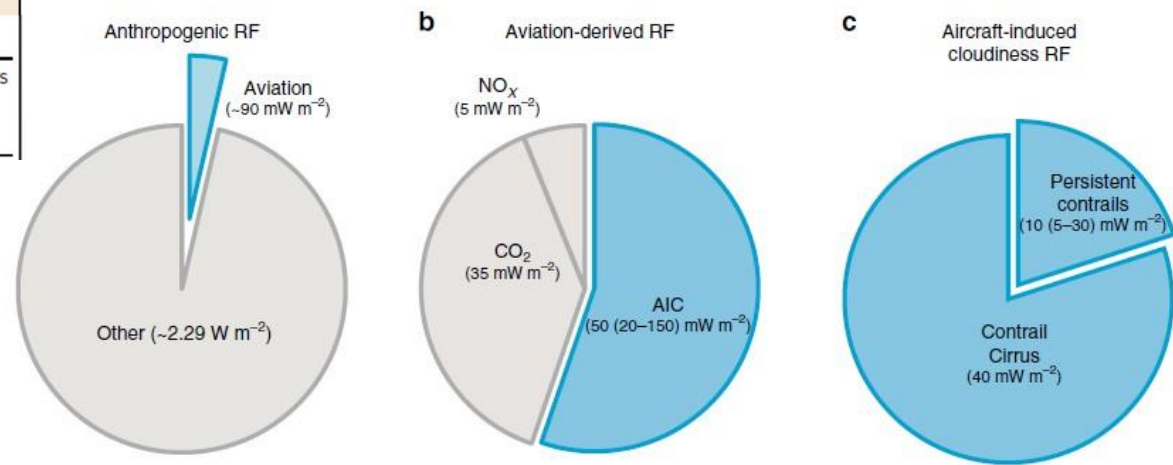
# Climate Impacts of Aviation Induced Cloudiness

Lee et al., Atm Env, 2021



B. Kärcher, Formation and radiative forcing of contrail-cirrus, Nature Communications, 2018

Table 1 Characteristics of contrails and contrail cirrus			
AIC	Short-lived	Long-lived	
Ice cloud type	Contrail	Persistent contrail	Contrail cirrus
RF potential	Negligible	Small	Large



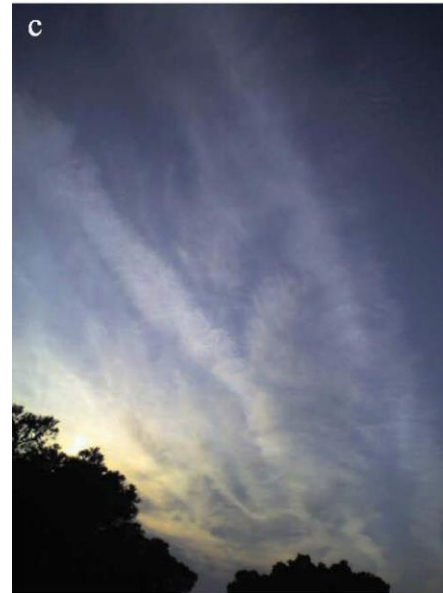


# Aviation Induced Cloudiness



Photographs of contrail spreading into cirrus taken from Athens, Greece, on 14 Apr 2007 at 1900, 1909, 1913, and 1920 local time (from top left to bottom right). Courtesy of Kostas Eleftheratos, University of Athens, Greece. →

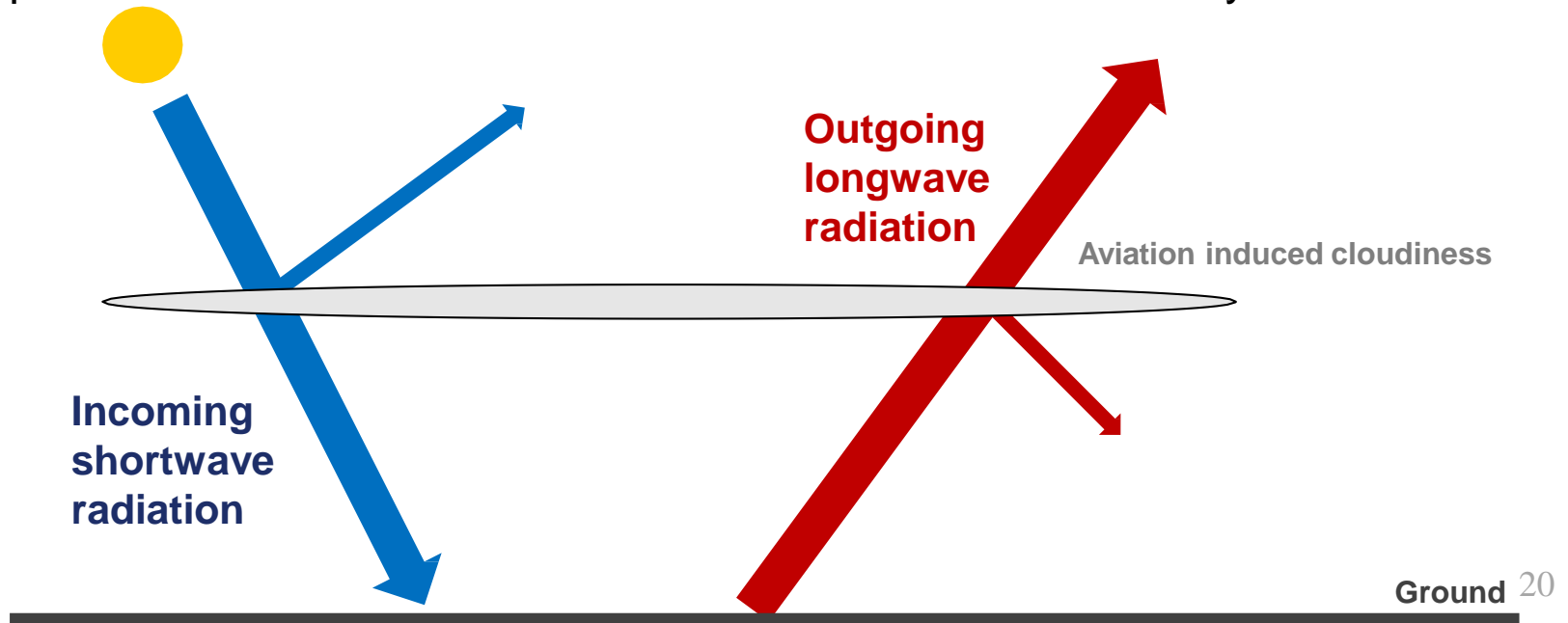
From: Heymsfield et al. BAMS 2010



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## Aviation Induced Cloudiness – Some Basics

- Contrail formation and aviation induced cloudiness determined by atmospheric conditions – contrails can form and disappear, or can form and persist, depending on temperature and humidity where the aircraft is flying
- Climate impact of aviation induced cloudiness is due to small differences in the amount of incident solar radiation and outgoing heat from the planet
- Magnitude and sign of climate impact is determined by season, time of day, and presence of other clouds underneath the aviation induced cloudiness
- Impact is measured in minutes to hours - if aviation activity were to stop, the impact of aviation induced cloudiness would cease within a day



# Potential Mitigation Measures for Aviation Induced Cloudiness

- Changing flight altitude / horizontal flight track (need to avoid / minimize increased fuel burn)
- Developing engines with changes in engine exhaust temperature / non-volatile particulate matter within exhaust
- Changing fuel composition with modifications to fuel sulfur content and fuel aromatic content

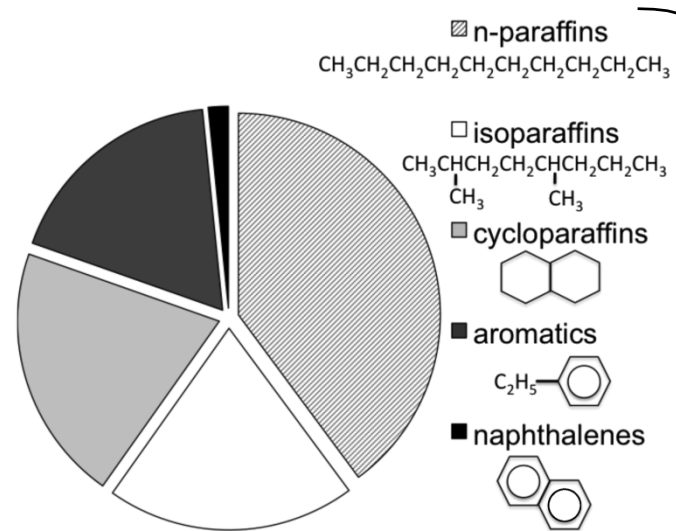
## Caution with contrail mitigation measures

- Need to weigh any changes in fuel burn carefully – time scales of impacts are very different
- Not all aviation induced cloudiness is climate warming and some is actually climate cooling



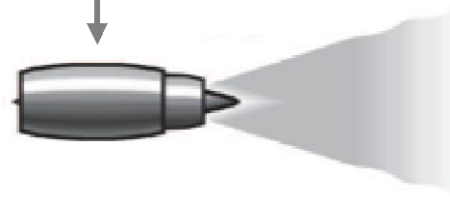
# Using Fuel Composition to Reduce Emissions

*Fuel composition and engine design determine emissions*



Fuel:  $\text{C}_n\text{H}_m + \text{S}$

Air:  
 $\text{N}_2 + \text{O}_2$



**Tank-to-Wake Actual Combustion Emissions**

$\text{CO}_2 + \text{H}_2\text{O} + \text{NO}_x + \text{SO}_x + \text{soot} + \text{CO} + \text{HC} + \text{N}_2 + \text{O}_2$

Weighted Mean Fuel Sulfur Content (PPM)		
	2006	2007
US East	446	321
US Gulf	858	800
US West	240	395
Nationwide	709	677

*Well established that fuel composition can be modified to reduce soot and  $\text{SO}_x$  emissions*

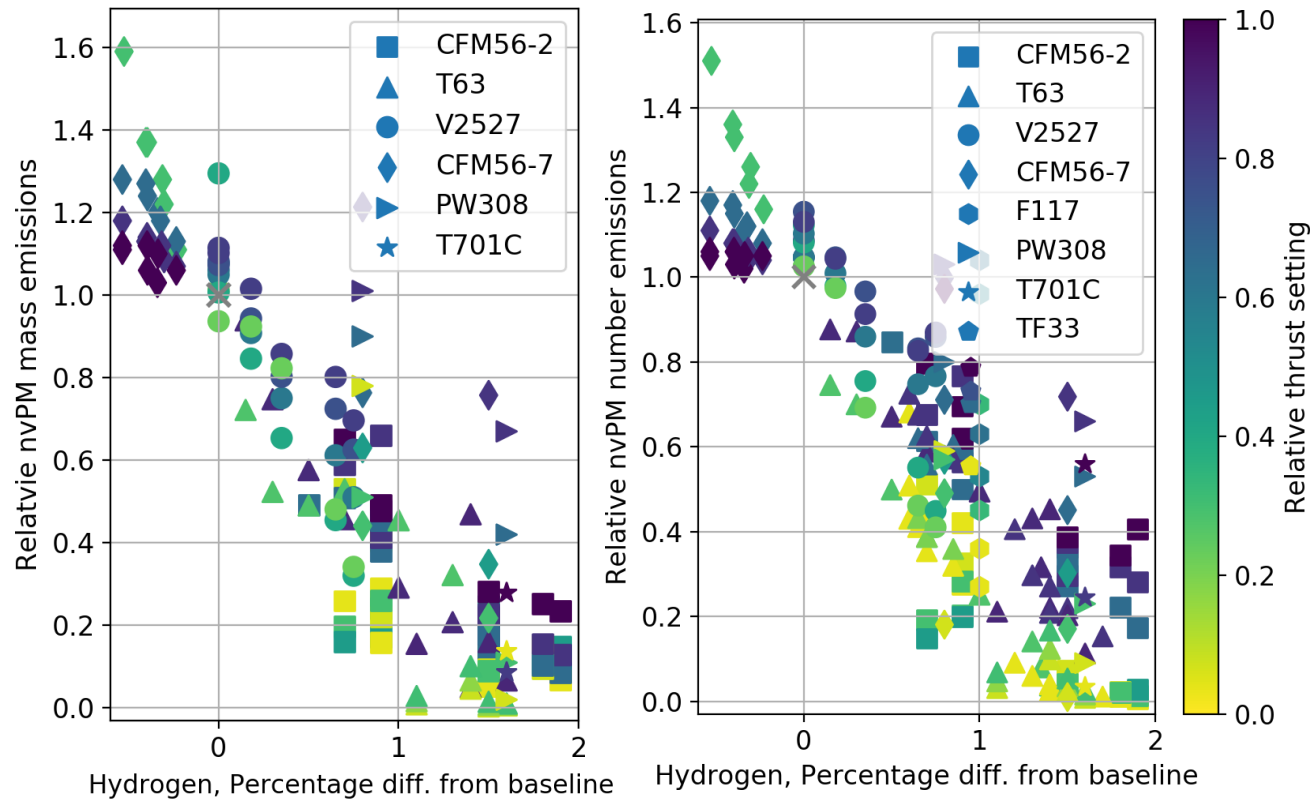
Terms “soot”, “nvPM”, “primary PM<sub>2.5</sub>”, and “BC” are used interchangeably in this briefing



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# Fuel Composition and non-volatile Particular Matter (nvPM)

- Relative nvPM emissions decrease with increasing hydrogen content (i.e., decreasing fuel aromatics content)
- Effect of fuel composition decreases with engine thrust setting
- Combustor design can also give significant reductions in nvPM emissions



***Similar trends for mass and number emissions***



# Aviation Induced Cloudiness (AIC) and SAF

- Contrails form from condensation of water
- Aviation induced cloudiness is composed of ice crystals that form from persistent contrails
- **Changing fuel composition effects:**
  - Hydrogen-to-carbon ratio (hence amount of H<sub>2</sub>O vapor in the engine exhaust) – *SAF combustion results in more water vapor*
  - Number of soot particles (nvPM) in the exhaust – these particles are condensation nuclei for contrails and aviation induced cloudiness – *SAF combustion produces fewer particles*
  - Sulfur oxides in the exhaust have an impact on how ice forms on the soot particles – *SAF combustion has no sulfur oxides*
- **Effect of SAF on warming from AIC depends on the balance of these competing effects (while accounting for uncertainties of each effect)**

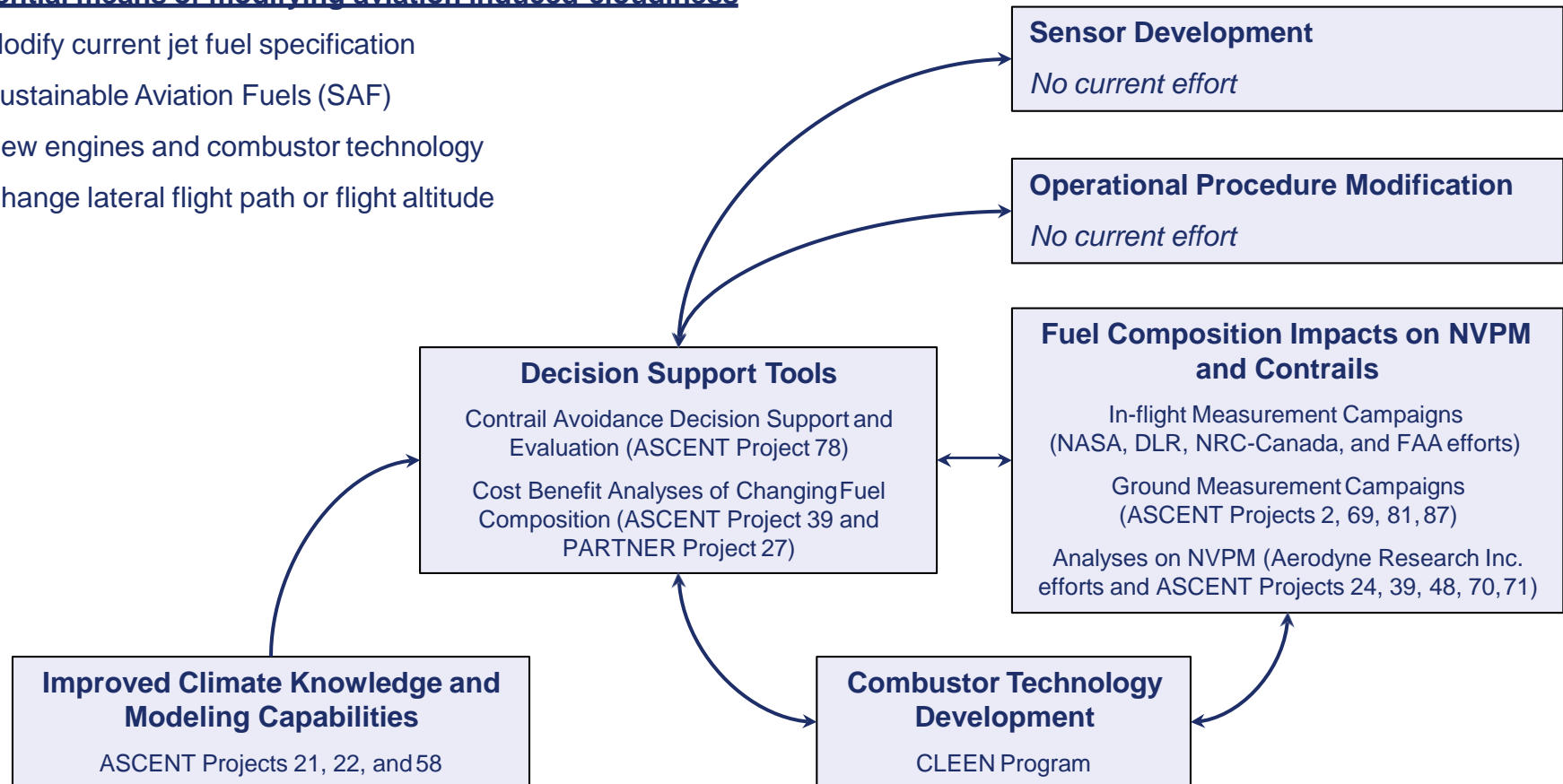


# FAA Efforts Related to Aviation Induced Cloudiness (AIC)

FAA supporting research on multiple fronts to examine measures that *could* mitigate aviation's impact on climate change through modification to contrails and aviation induced cloudiness

## Potential means of modifying aviation induced cloudiness

- Modify current jet fuel specification
- Sustainable Aviation Fuels (SAF)
- New engines and combustor technology
- Change lateral flight path or flight altitude





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**Email: [prem.lobo@faa.gov](mailto:prem.lobo@faa.gov)**

